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ADDRESS OF THE RETIRING PRESIDENT OF THE SOCIETY, AT THE SEVENTH ANNUAL MEETING, MARCH 30, 1895.

By W. W. CAMPBELL.

That there is greater public interest taken in astronomy than in any other department of science may be accepted without question. That fact is manifested by the gifts of money for establishing and supporting observatories; by the number of visitors to observatories; by the demand for astronomical literature in the newspapers; and by the large membership of our astronomical societies.

This being true, it is important that correct ideas should exist of what astronomers are trying to do. Visitors to observatories are intensely interested to learn the nature of our work, but not one in a score has a definite idea on that subject. A general opinion prevails that it is the duty of an astronomer to sweep the heavens with his telescope, in order to find new bodies—comets, planets, new stars, etc. While we in no way discourage the search for new and unknown objects, we may say that, relatively, very few professional astronomers engage in that work, either systematically or occasionally. The great observatories, with their expensive equipments, cannot afford to engage in such uncertain work. They leave it either entirely to the small observatories or to the amateur astronomer, or else they make it a very subsidiary matter. Thus the LICK Observatory devotes, possibly, one-twenty-fifth of its energies, but much less than one-twenty-fifth of its equipment, to looking for new objects. Similarly the other great observatories — Greenwich, HARVARD, Paris, Pulkowa, Washington — are doing little or nothing in that line.

The large majority of our unexpected comets are discovered by private or amateur astronomers. The expected returns of periodic comets are largely detected by professionals, for the double reason that they know when and where to look for them without great loss of time, and it is generally an advantage to search for them with large telescopes, which, unfortunately, amateurs do not possess.

"New stars" constitute a field of superlative importance. It is open alike to professionals and privates. Of the five new stars discovered since 1866, three are due to amateurs, and two to professionals.

Seven satellites of our solar system have been discovered in the last fifty years. The first of these, *Hyperion*, was discovered by a HARVARD College observer, and, independently, two days later, by a private astronomer in Liverpool. Of the other six, three were discovered in this country by professionals, and three by the Liverpool private observer. Yet, this is a field open only to large telescopes, and is not a fair test of the efficiency of private work.

The history of variable stars is similar to that of comets and new stars. The random searching for variable stars is nearly all done by private observers. They have very many discoveries to their credit. Nearly all of the observations for determining their periods and other circumstances of variation are made by private means.

In a similar manner, we could multiply cases showing the commendable activity of private observers in searching for new and unexpected objects, and, at the same time, showing that this field is not occupied by many professionals.

It may be asked: If these subjects may be, and are, left so largely to private observers, what is left for the professionals? Nearly everything is left to the latter. The astronomer's work has only just begun when the new object is discovered. Besides, there are the more interesting and valuable old and well-known bodies which are furnishing us an infinite field for investigation.

Professor SEDGWICK has given us one of our best definitions of scientific work. It runs something like this: Scientific work consists in the collection of facts and numerical results, and their arrangement in such a form that the general principles and laws of the science become apparent. That may be taken as the guiding principle of every astronomer. It matters little if new stars, comets, nebulæ, variable stars, are simply discovered. Unless they are investigated, the science of astronomy is not advanced. It is as if EUCLID had discovered that there is a science of the circle and the sphere, but had not investigated its laws. It is as if NEWTON and LEIBNITZ had discovered that there is a process in mathematics which we call the calculus, but had stopped before developing its general principles. It is as if the chemist had discovered that there is an element called oxygen, but had stopped before deducing its properties. It is as if COPERNICUS had been contented, like his neighbors, in noting the existence of the principal heavenly bodies, and had not investigated their motions. The laws of geometry, of calculus, of chemistry, of astronomy, have always existed. They are a part of general truth. The scientist does not invent them. He finds them out by investigating in those fields, and makes advances, as SEDGWICK pointed out, by the collection and systematic study of facts and numerical results.

The aim of astronomical science is analogous to that of biological science. The greatest problem presented to Darwin, to his predecessors and successors, is that of the history of organic life. It embraces not only a full knowledge of every form of life that exists, or that ever existed, but, most of all, of the relations existing between the different grades and forms. In the same way we may say that the ultimate problem of astronomy is that of the history, on a large scale, of inorganic life—of the sidereal universe. The Sun, the planets, their satellites, the comets, the meteors, the zodiacal light, are before us to be investigated. In the sidereal system we have tens of millions of stars, tens of thousands of nebulæ, star clusters, and double stars. We want to know every possible fact about these objects, not for the sake of the facts themselves, but because of the general principles which they will enable us to discover. We want to know their past history, their present condition, the future in store for them. We want to know their origin and end, and, most of all, we want to know how the different classes of objects are related to each other.

It is quite impossible to explain in detail how the astronomer conducts his investigations, but one or two examples will be given in outline.

Let us take the case of a comet. Its discovery, together with its position in the sky, is announced by telegraph to all the observatories which are known to desire that information, and those interested in cometary astronomy carry on the particular investigations for which they have suitable apparatus. In the first place, there are generally very many observers who determine from night to night the positions occupied by the comet. The first half-dozen, or more, observations are published as speedily as possible, the American observations being generally sent by telegraph to Cambridge, Mass. The first three observations secured on different dates are used by some skilled computer, who in a few hours computes an approximate orbit of the comet, determines the approximate positions in which it will be found in the next few weeks, and sends the information by telegraph to the observatories. The position of the comet continues to be observed, and a more accurate orbit is computed. We soon learn whether the comet is moving through the solar system in a parabolic orbit, never to return to us, or whether it is moving in an ellipse, and is, therefore, to remain with us as a somewhat permanent member of our system. If it is a periodic comet, is it identical with any comet previously observed? If so, the circumstances of its motion in the intervening time are fully discussed. If it is a periodic comet not previously observed, there exists the question of its origin. Was the comet on its passage through our system moving near enough to any of the large planets—*Jupiter*, *Saturn*, etc.—to be captured by them and by the Sun, as many of our periodic comets probably were, and compelled to remain in our system?

The positions of the comet continue to be observed with the utmost accuracy, as long as it remains visible. After its disappearance, all these observations are made use of by an experienced computer, who determines, by processes usually requiring several months' labor, the best possible orbit of the comet, discussing every circumstance of its motion. If it is a faint parabolic comet, moving away never to return, the subject of cometary astronomy is not advanced appreciably by all these careful observations and computations. There are dozens of such comets which have come and gone without telling us anything new, and one is almost unguarded enough to wish that they would remain undiscovered. That is not the case, however; astronomers do not regret the time and energy devoted to the work, and one does not know beforehand how useful his labors may be.

If the comet is a bright one, it is further investigated in many ways. A few years ago its form and appearance would have been accurately drawn. Now it would be photographed as often as possible. The photographic record of its progress from a distant faint object to a bright and complex near object, together with its subsequent decline, would be made as complete as possible. These photographs would be measured and studied to see if they would yield up the secrets of the mysterious comet-forms. The comet would be observed with the spectroscope to determine its condition and its constitution. Its spectrum would be accurately measured and photographed, and compared with all other spectra which could possibly shed any light upon its constitution. It would be observed with the polariscope to determine whether its light is inherent or reflected. Not only would the individual comet be investigated in as many directions as possible, but there remains the study of comets in general. The facts gathered by observers about all comets would be arranged with great skill, to see if the general principles concerning them could be recognized. We want to understand the origin of comets, but we know little or nothing as to how they originate. We want to learn how they form their tails; why the forms of the tails should change so rapidly; why they should be repelled by the Sun; — but as yet we know little or nothing along those lines. We want to know their physical condition and their chemical constitution. We still have many unsettled questions in those fields of inquiry. We would like to know how comets are related to other classes of celestial objects — to the nebulæ, for instance. What is the place of comets in the line of sidereal evolution? In regard to the last question, we know that some of our meteor streams have resulted from, and are, the remains of disintegrated comets, and that is about the extent of our knowledge.

The preceding suggestions indicate a few of the lines in which comets would be studied. There would not be space in this paper to give even a small fraction of the detailed questions which we would ask and try to answer in regard to a bright comet, and comets occupy only a small corner in the astronomical field. They excite great interest, not only because they are extremely interesting objects in themselves, but because they come close to us, and because, since they come and go, they must be studied while they are here. We overlook, sometimes, the greater importance of the old and well-known objects, because they are always with us. These familiar objects illustrate world-life in essentially all its stages of development. Do we want to acquire the secrets of the stars? If so, we must begin by studying our Sun. The Sun, though not one of the largest stars, happens to be the nearest star. There are observatories established for the sole purpose of investigating the Sun, and a great many observers are constantly employed in its visual, photographic, thermal, and spectroscopic study. Eclipse expeditions are sent to all quarters of the globe to observe the Sun's corona. Solar research has already resulted in numerous important discoveries, but many of the old questions are still unanswered, new questions are coming up, and the work is still in its infancy. How much more difficult and more extensive must be the study of the distant suns and the nebulæ. They are to be investigated at every point. Let me give an outline of the methods used by an astronomer at one point. We want to know how the nebulæ are related to the stars. We know that, by the operation of natural laws, the nebulæ must be radiating heat into the cold surrounding space, and we think they must be contracting in size. It is a working hypothesis that stars are formed by the condensing of nebulous matter. In the great nebula of *Orion* there are to be seen some interesting groups of stars, which it is suspected may be situated within the nebulous matter. Are those stars actually associated with the nebula,—formed from it, so to speak,—or do we simply see them projected upon the nebula because they happen to lie between us and the nebula, or on the other side of the nebula? The astronomer who wants to settle that question does not sit at the end of his telescope and wait for the nebula to change before his eyes, nor for a new star to be formed. It probably requires thousands, and possibly tens of thousands, of years for appreciable changes to occur. He must study the nebula as it is at present, and the stars just as they are at present. The observer puts his spectroscope on the telescope, not to make an immediate discovery, but to begin an investigation requiring, possibly, a dozen or more nights' work. He enters the dome each night, not in the expectation of settling the question, but to carry out a program of work which he has previously arranged. He will investigate the spectra of the nebula and of each of the stars in question as fully as possible. When all the facts have been secured, he will compare the spectra with each other, noting the coincidences and the discordances. The spectra will prove to be closely related. They support the theory that the stars — that those stars, at least, — have been formed from nebulous matter. But can we say that those stars are situated within the *Orion Nebula?* No; because there are stars in other parts of the sky possessing similar or identical spectra. The *Orion* stars which are in question may be within the present *Orion Nebula*, or they may have been formed from the outer portions of the *Orion Nebula* when that nebula was vastly larger than it is at present; or they may have been formed from other nebulæ which happened to lie in that direction, either between us and the *Orion Nebula*, or beyond the *Orion Nebula.*

I wish it were possible to give here an idea of the valuable and extensive investigations which have been made with meridian instruments, and to outline the methods of work. Until a few years ago, at least one-third of the energies of astronomical workers was devoted to making and reducing observations with the meridian circle. Those observations have given us our star catalogues, containing the accurate positions of a hundred thousand stars, and the approximate positions of five times as many. These star catalogues are the foundation and the framework on which all accurate mathematical astronomy is built, and it is impossible to overestimate their value. This work, requiring great skill, infinite patience, unending toil, is almost wholly unknown to the public, and yet it is astronomy's richest possession.

In whatever line of investigation an astronomer is engaged, it is the inviolable rule to work with the utmost accuracy, even though such accuracy may seem superfluous. We can never tell what great discovery is lurking beneath the surface, ready to be buried by careless observations, and equally ready to be uncovered by refined observations. The greatest recent discovery in astronomy, the variation of terrestrial latitudes, would not have been possible had not our meridian-circle observers striven for the utmost accuracy. The fact that the latitude of a point on the earth's surface varies was revealed by observations made for an entirely different purpose, viz.: for the accurate determination of the positions of stars in the sky. The newly discovered element in our atmosphere, argon, admirably illustrates my point. Its discoverer was engaged in determining the specific gravities of the permanent gases with greater accuracy than had hitherto been attained. In the course of his work, he found that nitrogen taken from the atmosphere was about half of one per cent. heavier than nitrogen taken from definite chemical compounds. An investigation of the possible causes of the discrepancy led to the discovery of the heavier element, argon, combined with the atmospheric nitrogen. Early in the present century, some noted astronomers held, and even expressed, the opinion that the Sun-spots occur at random, without reference to any law; yet, a private astronomer, by observing them accurately and systematically for 40 years, came easily upon the 11-year periodic law of Sun-spots.

Those of our members who have telescopes, some leisure, and great zeal, can, as pointed out at the beginning of this paper, do useful work by discovering new objects. The fields which are open to the private astronomer for pure investigation are more limited, but they are limited only by his personal opportunities. We need only to recall the excellent work of many private astronomers to realize that fact. There is always the question of how to begin. Perhaps I may close this paper with the suggestion that a good way to begin, possibly the best way, is by doing what some other astronomer has already done, or by reviewing and repeating all the observations along a certain line. One will very soon find related fields of work still unexplored, and will have acquired the ability to enter them successfully. That the researches undertaken by the private astronomers in this Society may be many, and be limited only by their opportunities, is the best wish of the retiring President.